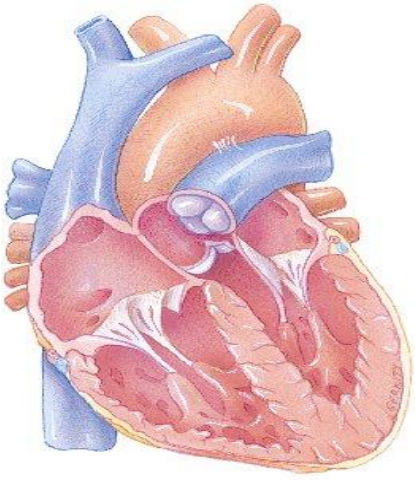
Topic:

This research work is about the mathematical modeling of cardiovascular system, subsystem using Lumped parameter model and simulation of these models using MATLAB software. Here the word system means an interconnected set of elements that function in some coordinated fashion. Thus the human heart, with its muscles, nerves and blood, may be regarded as a system. The heart is merely a subsystem of the entire circulatory system.

Introduction:

- The Cardiovascular System:



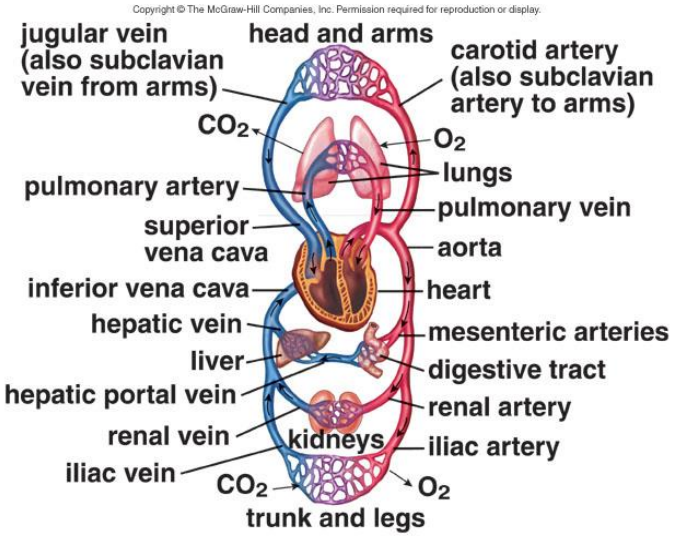
- The Heart
  – Covered by the pericardium.
  – Has two sides with two chambers.
  – Blood flows through the heart in one direction.
  – Valves control the blood flow. The cardiac conduction system controls the electrical impulses that cause the heart to contract
  – Bicuspid (mitral) valve.
  – Tricuspid valve.
  – Pulmonary valve
  – Aortic valve.

- **Circulation**
  Circulation **–** pumping of blood through the entire body by the heart**.**

  – Coronary circulation – the circulation of blood within the heart.

  – Pulmonary circulation – the flow of blood between the heart and lungs.

  – Systemic circulation – the flow of blood between the heart and the cells of the body.



The Pulmonary Circuit:

- The *pulmonary circuit* begins with the *pulmonary trunk* from the right ventricle which branches into two *pulmonary arteries* that take oxygen-poor blood to the lungs.
- In the lungs, oxygen diffuses into the blood, and carbon dioxide diffuses out of the blood to be expelled by the lungs.
- Four *pulmonary veins* return oxygen-rich blood to the left atrium.

The Systemic Circuit:

- The *systemic circuit* starts with the aorta carrying O_2-rich blood from the left ventricle.
- The aorta branches with an artery going to each specific organ.

Generally, an artery divides into arterioles and capillaries which then lead to venues.

- The vein that takes blood to the vena cava often has the same name as the artery that delivered blood to the organ.
- In the adult systemic circuit, arteries carry blood that is relatively high in oxygen and relatively low in carbon dioxide, and veins carry blood that is relatively low in oxygen and relatively high in carbon dioxide.

This is the reverse of the pulmonary circuit

- The ***coronary arteries*** serve the heart muscle itself; they are the first branch off the aorta.
- Since the coronary arteries are so small, they are easily clogged, leading to heart disease.

The *hepatic portal system* carries blood rich in nutrients from digestion in the small intestine to the liver, the organ that monitors the composition of the blood

Blood Flow:

- The beating of the heart is necessary to homeostasis because it creates pressure that propels blood in arteries and the arterioles.
- Arterioles lead to the capillaries where nutrient and gas exchange with tissue fluid takes place.
- *Blood pressure* due to the pumping of the heart accounts for the flow of blood in the arteries.
- Venous blood flow is dependent upon: Compression of veins causes blood to move forward past a valve that then prevents it from returning backward.

Review of Literature:

In the literature there has been several approaches to integrate different levels of circulation.

Mostly, models based on lumped representations were employed to accomplish this task Spencer and Deninson (1959); Schaaf and Abbrecht (1972); Liang and Liu (2005); Korakianitis and Shi (2006); Lanzarone et al. (2007); Reichold et al. (2009), incorporating 0D models to simulate flow in the larger arteries, veins and cardiac circulation.

As well, distributed models for simulating the blood flow in compliant vessels has been an exhaustive area of research through the last decades Avolio (1980); Stettler et al. (1981); Kufahl and Clark (1985); Stergiopulos et al. (1992); Olufsen et al. (2000);Wang and Parker (2004); Reymond et al. (2009).

- William Harvey established the concept of circulation of blood in 1628, numerous attempts have been made.
- The fact that the arterial tree transforms intermittent flow from the left ventricle to steadier outflow was recognized by Hales in 1733. He describe the arterial system as a single elastic chamber which later become known as the Windkessel model (Frank, 1899)
- A. P. Avolio had constructed multi-branch model of the human arterial system based on the anatomical branching structure of arterial tree. (1980).
- Olfusen and Nadim derived a lumped model for the blood flow and pressure in systemic arteries using the equations of fluid dynamics (2004).
- Hassani ET al.represent a model with 42 compartment, which describe the arterial system.

Objectives:

Since the pioneering work of Otto frank in 1899, there have been many types of mathematical models of blood flow. The aim of these model is a better understanding of the cardiovascular system with its more components then the previous one. The aim of doing Simulation is to facilitate the understanding of cardiovascular system in an inexpensive and noninvasive way. The presented model is a one of the useful tool in studying the physiology of cardiovascular system and the related diseases. We can able to calculate pressure and blood flow in particular blood vessel.

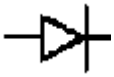
Plan of work and Methodology:

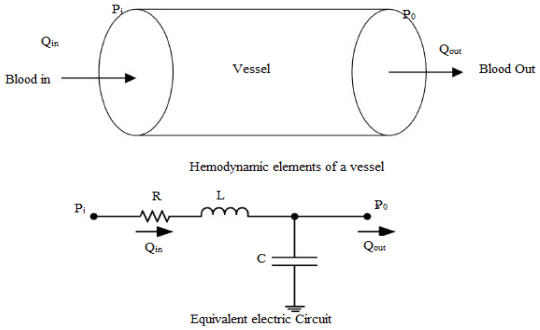
The whole work is organized in following way and divided in to five chapters.

Chapter 1 reviews the basic concepts in cardiovascular physiology. It describe the functions of the cardiovascular system with its parts. Some control mechanisms in the cardiovascular system are also discussed. It includes the baroreceptor loop and the local metabolic control.

Chapter 2 deals with analogy of cardiovascular system with electrical Circuit. In this chapter we explain how we analog blood vessel with RLC circuit. This RLC model is known as Lumped Parameter model.

Chapter 3 presents mathematical models of cardiovascular system in its different subsystems, Models without control system and with baroreceptor. We divide whole circulatory system in pulmonary circulation and systemic circulation. Also Focus on Arterial and venues circulation. Model is derived on based of Lumped parameter Method under certain assumption. Lumped parameter models are in common use for studying the factors that affect pressure and flow waveforms.

Cardiovascular System	*Vessel Resistance (R_c)*	*Vessel Compliance (C_c)*	*Blood inertia (L_c)*	*Valve*
Electronic Circuit & Symbols	*Electrical Resistance(R_e)*	*Capacitance (C_e)*	*Inductance (L_e)*	*Diode* 



Under this concept we form the mathematical models as a set of linear ordinary differential equations, which represent the required models of different subsystem. The models represent relationship between pressure, blood flow and blood volume.

Chapter 4 provides Numerical computation and Simulations of the models derived in chapter 3 using Matlab software. Simulations of the pressure and volume curves, pressure and blood flow curves of different blood vessels are presented. Following formulas are taken for simulation

Blood vessels resistance = $\frac{8l\mu}{\pi r^4}$

Blood inertia L = $\frac{9l\rho}{4\pi r^2}$

Vessel compliance C = $\frac{3l\pi r^3}{2Eh}$

Where μ = blood viscosity = 0.049 gram/cm. sec., ρ = blood density = 1.05 gram/cm^3.

Anatomic and physiological data like Length, Radius, Wall thickness and Young's module, wave speed of vessels for circuit parameters, have been taken from medical textbooks and articles and where needed calculated using appropriate formulas.

Chapter 5 summarizes the results obtained in this study. Comparison of obtained graphs with actual standard graphs mention in different literatures and model validation. Moreover, the limitations of the model and further investigations are presented.